AFRL-RV-PS-
TP-2013-0002

AFRL-RV-PS-
TP-2013-0002

EDUCATIONAL PROGRAMS: INVESTMENT WITH A LARGE RETURN (POSTPRINT)

David Voss, et al.

ATA Aerospace, LLC
1300 Britt St SE
Albuquerque, NM 87123-3353

10 December 2013

Technical Paper

APPROVED FOR PUBLIC RELEASE; DISTRIBUTION IS UNLIMITED.

AIR FORCE RESEARCH LABORATORY
Space Vehicles Directorate
3550 Aberdeen Ave SE
AIR FORCE MATERIEL COMMAND
KIRTLAND AIR FORCE BASE, NM 87117-5776

DTIC COPY

NOTICE AND SIGNATURE PAGE

AFRL-RV-PS-TP-2013-0002 HAS BEEN REVIEWED AND IS APPROVED FOR PUBLICATION IN ACCORDANCE WITH ASSIGNED DISTRIBUTION STATEMENT.

//SIGNED//	//SIGNED//
David Voss, Work Unit Manager	JOEL B. MOZER, DR-IV Chief, Integrated Experiments and Evaluation Division

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
10-12-2013

2. REPORT TYPE
Technical Paper

3. DATES COVERED *(From - To)*
29-Jun-07 - 29-Oct-12

4. TITLE AND SUBTITLE
Educational Programs: Investment with a Large Return (Postprint)

5a. CONTRACT NUMBER
FA9453-07-D-0189/0008

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
62601F

6. AUTHOR(S)
David Voss, Kelly Alexander, Melody Ford, Christopher Handy, Steven Lucero, Amanda Pietruszewski

5d. PROJECT NUMBER
8809

5e. TASK NUMBER
PPM00004247

5f. WORK UNIT NUMBER
EF000357

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
ATA Aerospace, LLC
1300 Britt St SE
Albuquerque, NM 87123-3353

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Air Force Research Laboratory
Space Vehicles Directorate
3550 Aberdeen Ave. SE
Kirtland AFB, NM 87117-5776

10. SPONSOR/MONITOR'S ACRONYM(S)
AFRL/RVEP

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
AFRL-RV-PS-TP-2013-0002

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited. (377ABW-2012-0761 dtd 06/25/2012)

13. SUPPLEMENTARY NOTES
"Government Purpose Rights"
25th Annual AIAA/USU SmallSat Conference, Logan, Utah, 6/27/2012

14. ABSTRACT
Educational programs provide opportunities for organizations and individuals to help shape the direction of the aerospace industry while strengthening their own competitive edge. With an engaged customer, a rigorous educational program, and a motivated student community, innovative ideas translate to actual programs and true scientific or technological investigations at a significantly lower cost while continuing to inspire the next generation of aerospace engineers. The University Nanosat Program (UNP) is one such example that attempts to partner schools, agencies, companies, and individuals across the community to provide a requirement-based, small satellite (pico/nano/micro satellite class) education. The recent launch of FASTRAC (microsat) and the upcoming launches of CUSat (microsat), DANDE (microsat), COPPER (CubeSat), and Ho'oponopono (CubeSat) point to the program's success, which is already illustrated by the large number of UNP graduates contributing to the global small satellite community. Programmatic lessons learned from the current satellite efforts will be briefly discussed in addition to some of the current efforts to leverage the highly capable group the UNP community represents.

15. SUBJECT TERMS
University Nanosat Program (UNP), CubeSat

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCL	UNCL	UNCL	Unlimited	14	David Voss
					19b. TELEPHONE NUMBER *(include area code)*

This page is intentionally left blank.

SSC12-VII-1

Educational Programs: Investment with a large return

David Voss, Kelly Alexander, Melody Ford, Christopher Handy, Steven Lucero, Amanda Pietruszewski
Air Force Research Laboratory
3550 Aberdeen Ave SE, Albuquerque, NM 87113; 505.846.5291

ABSTRACT

Educational programs provide opportunities for organizations and individuals to help shape the direction of the aerospace industry while strengthening their own competitive edge. With an engaged customer, a rigorous educational program, and a motivated student community, innovative ideas translate to actual programs and true scientific or technological investigations at a significantly lower cost while continuing to inspire the next generation of aerospace engineers. The University Nanosat Program (UNP) is one such example that attempts to partner schools, agencies, companies, and individuals across the community to provide a requirement-based, small satellite (pico/nano/micro satellite class) education. The recent launch of FASTRAC (microsat) and the upcoming launches of CUSat (microsat), DANDE (microsat), COPPER (CubeSat), and Ho'oponopono (CubeSat) point to the program's success, which is already illustrated by the large number of UNP graduates contributing to the global small satellite community. Programmatic lessons learned from the current satellite efforts will be briefly discussed in addition to some of the current efforts to leverage the highly capable group the UNP community represents.

INTRODUCTION

Program Overview

The University Nanosat Program's (UNP) primary objective is to provide the next generation of space engineers an opportunity to learn essential engineering principles through hands on development of spacecraft hardware. Technology development and university laboratory development are secondary and tertiary goals as seen in Figure 1.

Figure 1: UNP Objectives

The program has two phases: the competition phase and the delivery phase. The competition phase involves 10 to 12 universities competing to move on to the delivery phase. During the two year competition phase, all schools participate in a series of reviews: System Concept Review (SCR), System Requirements Review (SRR), Preliminary Design Review (PDR), Critical Design Review (CDR), Proto-Qualification Review (PQR) and Flight Competition Review (FCR). Over the past 10 years approximately 4500 undergraduate and graduate students from 28 universities have participated in the program. Six schools have moved into the post-FCR phase of the program and have either delivered and launched flight hardware or are in the process of delivering flight hardware. Through partnering with the Air Force Space Test Program (STP), two microsatellites have been launched and two more microsatellites have been manifested on upcoming launches. Currently five UNP CubeSats have been selected for launch through NASA's Educational Launch of Nanosatellites program (ELaNa). An overview of the UNP high level schedule can be seen in Figure 2 although it doesn't capture all of the satellites currently selected to fly through the ELaNa program.

The University Nanosat Program involves a number of overlapping satellite programs. Each program, and the length till delivery to AFRL, is dependent primarily on the university. One of the current efforts discussed later in this paper addresses the desire to reduce the delivery length from winning the competition to delivery to AFRL. Each competition begins in January of an odd year with the Broad Agency Announcement (BAA) for the competition coming out the summer before. The NS-8 BAA is currently scheduled to be released just prior to the 4th quarter FY12 and closed by September 2012.

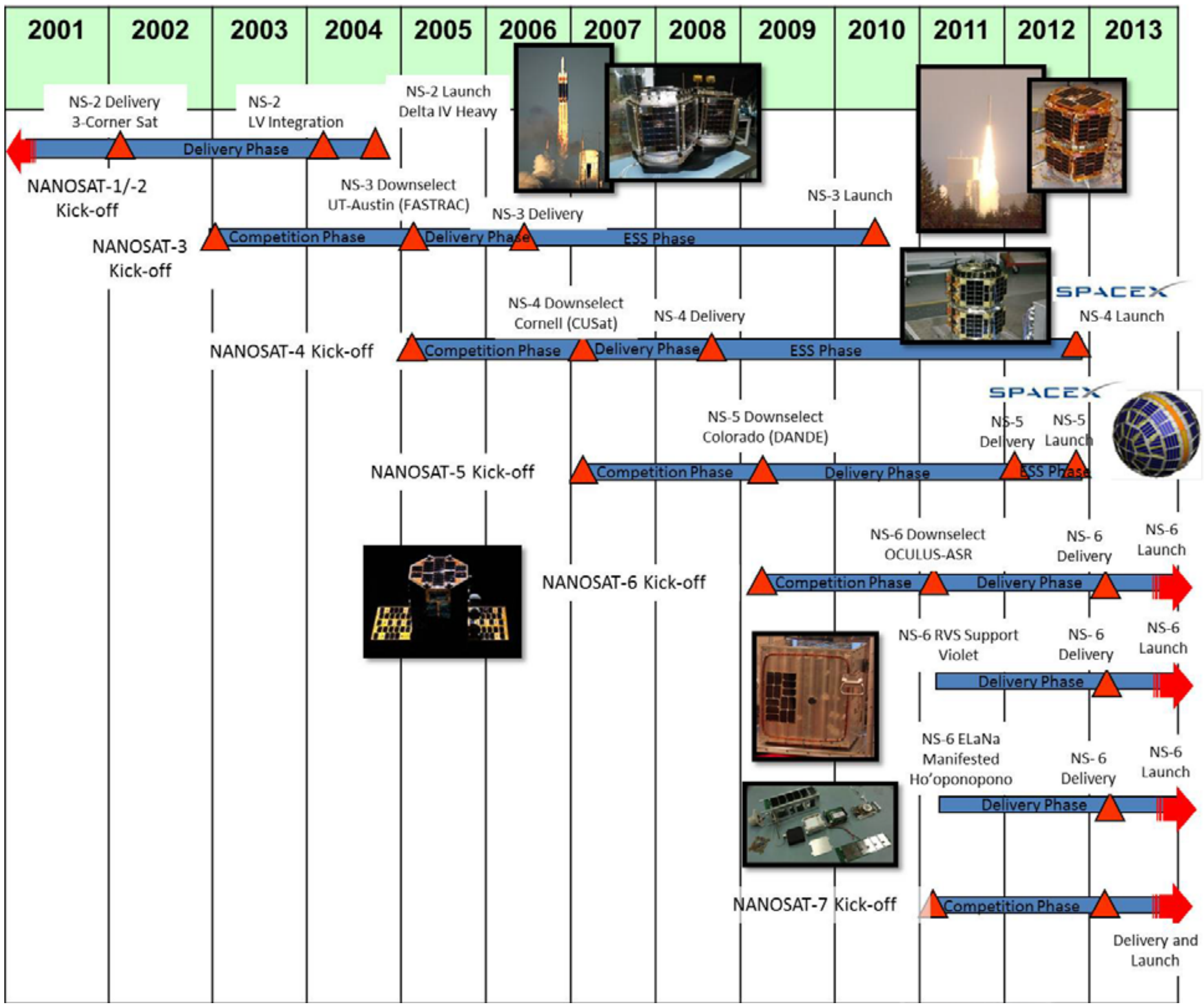

Figure 2: High level UNP schedule

Return on Investment

The need for training in Science, Technology, Engineering, and Math (STEM) is well established[1,2] and a particular challenge to the Aerospace community. The need is so great that it has been addressed in the US Space Policy as well as by the past two US Presidents as national priorities[3]. It was estimated in 2008 that 26 to 27 percent of the Aerospace workforce was eligible to retire[4]. In addition to the need to replace individuals who are planning to retire is the need for good systems engineering practices, the lack of which has been linked to cost overruns in large DoD programs[5]. UNP seeks to address these two significant challenges by both inspiring students to pursue space related fields as well as teaching good systems engineering principles. To date, the involvement in the program (4500 students at 28 universities) reflects the success of involvement at the academic level. Although difficult to track, internal UNP studies indicate a solid retention rate in aerospace fields within the government, industry, and academic areas.

These large programmatic goals oftentimes overshadow the numerous secondary benefits provided by the program. Many companies partner directly with school programs providing mentorship to students and giving the school a better opportunity to have their hardware flown. Additionally, it gives these experienced students the opportunity for permanent employment. Students working with a company are provided opportunities to learn requirements for flight hardware flying on their spacecraft, interact with professionals, and create career broadening opportunities. For professors (the spacecraft Principle Investigators (PI)), having a large, student-designed satellite program often provides a significant level of visibility at their respective school. This helps in establishing a laboratory, finding support for students, and creating many independent study projects.

Hundreds of hours of independent study are granted to UNP students each semester.

RECENT UPDATES/DEVELOPMENTS

Over the past year there have been a number of developments within the program and will be briefly described below.

FASTRAC Mission Success

The University of Texas's Formation Autonomy Spacecraft with Thrust, Relnav, Attitude, and Crosslink (FASTRAC) launched in November of 2010 and has since been performing mission operations following a long mission commissioning phase. FASTRAC experienced a significant number of challenges in their communication system[6] and later in the microcontroller for the GPS as discussed in an article published in the Journal of Small Satellites summer of 2012.

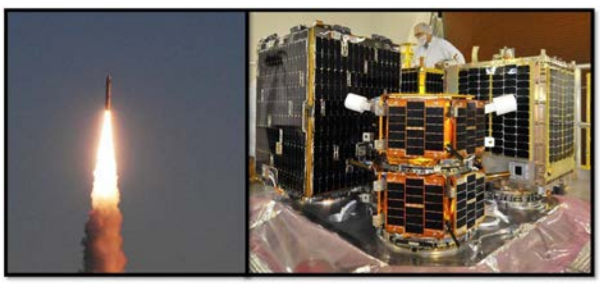

Figure 3: Launch of FASTRAC on the STP-S26 Mission. FASTRAC is the two satellite stack in the foreground.

Although FASTRAC was unable to meet full mission success it was able to meet all minimum mission success criteria, two of the three full mission success criteria for the primary mission, and full mission success for the secondary mission objective. The satellite has been made available several times to the amateur community for digipeating and will hopefully be useful for validating future UNP ground stations.

CUSat (NS-4) & DANDE (NS-5) Upcoming Launch

The NS-4 winner, CUSat, built by Cornell University, and the NS-5 winner, DANDE, built by the University of Colorado at Boulder, were previously scheduled to fly on the first NASA Commercial Resupply to the Space Station (CRS-1). However, due to changes in the orbit of CRS-1, CUSat and DANDE (shown in Figure 4) have been moved to an upcoming SpaceX launch currently scheduled for the end of 2012.

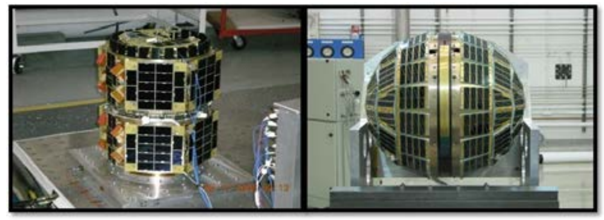

Figure 4: Cornell University built CUSat on the left and University of Colorado at Boulder built DANDE on the right, both scheduled to go up in December 2012.

CUSat is demonstrating the capability of millimeter ranging using Carrier Phase Differential GPS (CDGPS) between the two spacecraft as well as attitude determination using CDGPS. DANDE, which stands for Drag and Atmospheric Neutral Density Explorer, is investigating atmospheric drag in the ionosphere using a well-established ballistic coefficient, a neutral mass spectrometer, and a set of accelerometers. Currently, CUSat is in the final phases of Environmental Stress Screening (ESS) and performance validation testing at AFRL. DANDE is in the initial phases of ESS and performance validation testing. A number of lessons learned will be discussed later in this paper with respect to the delivery of CUSat and DANDE to AFRL.

UNP CubeSats Launching through ELaNa

With the advent of NASA's ELaNa program, the regular UNP programmatic flow has been interrupted for the better. Historically, access to space was extremely rare, and only through means such as UNP were educational programs able to access space. UNP relied solely on the Space Test Program to provide access to space for its winner as reflected by the launch of 3-CornerSat (NS-2), FASTRAC (NS-3), and the upcoming launches of CUSat (NS-4) and DANDE (NS-5). This led to the misperception that the primary purpose of UNP was to provide access to space. Although access to space is a key benefit to UNP, the primary objective of the program from the Program Office's perspective is the structure provided to academic programs through the scheduled reviews and the independent assessments of each program in the competition. UNP strives to find the balance between applying the typical standards of documentation and testing of a Class A spacecraft, and the minimum amount of documentation and testing required to produce a reliable satellite that is going to work in space. Student-run hardware programs are oftentimes driven by schedule and lose sight of the big picture systems engineering perspective. This results in performing a reduced set of test and design that is far below the minimum threshold. A well designed educational program should take into account the capabilities of the laboratory, the personnel available for mentorship, and the strengths and resources of the school when selecting hardware programs. If schools are unable to commit to the rigor of a satellite effort then there are other great hardware educational programs with a quicker return on the investment such as high altitude balloon launches or sounding rockets. UNP strives to support those academic programs which choose student-developed, flight-worthy, satellite hardware.

This is very complimentary to the ELaNa program that is committed to providing access to space. Although there has historically only been one winner of the UNP competition, the Program Office will strive to support each UNP satellite that is manifested through other means. Recently this was illustrated when the University of Hawaii's Ho'oponopono was selected to be manifested in January 2011. The University of Hawaii placed third in the NS-6 competition but applied for ELaNa independently and was selected to be launched. As a result, the UNP Program Office decided to provide financial support to Hawaii as well as support for independent assessment design reviews and environmental testing services. With the five CubeSats currently selected to be manifested by ElaNa (some shown in Figure 5), it may not be possible to provide this level of support due to the Program Office's limited resources; however, the Program Office intends to support in some way each program that desires it, even if it looks differently.

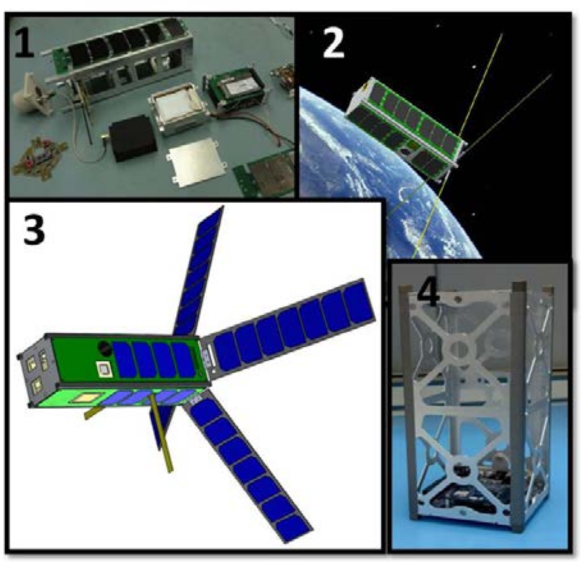

Figure 5: (1) University of Hawaii's Ho'oponopono, (2) University of Texas's Armadillo, (3) University of Michigan's CADRE, (4) St. Louis University's Argus bus (St. Louis University's Copper not shown).

Oculus-ASR (NS-6) & Violet (NS-6) Development

Michigan Technological University's Oculus-ASR was the winner of the NS-6 competition and is currently in the two year delivery phase. Although slightly behind the desired delivery schedule, the Pre-Integration Readiness Review (PIR) is scheduled for December 2012. Oculus-ASR's mission is to provide space-based optical calibration capabilities for ground based telescopes. Oculus-ASR was briefed to the Department of Defense (DoD) Space Experiments Review Board (SERB) in the summer of 2012 and ranked 34 out of 62 experiments. This was the highest ranking for a UNP satellite to date and reflects the Program Office's efforts to increase the military relevance of the UNP program. Also briefed to the SERB was the NS-6 runner up, Violet, built by Cornell University. Violet is being sponsored by AFRL's Space Components and Technologies Division's (RVS) Guidance, Navigation and Control (GNC) group and is managed through UNP in conjunction with RVS personnel. Both Oculus-ASR and Violet satellites can be seen in Figure 6. Due to contracting issues Violet started the post-FCR process nearly a year after the FCR date.

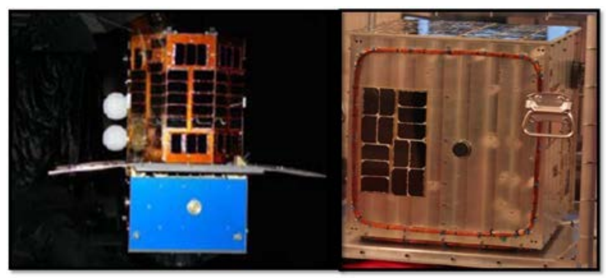

Figure 6: (left) Michigan Technological University's Oculus-ASR, (right) Cornell University's Violet

UNP PROGRAM OFFICE CHANGES

The University Nanosat Program is a partnership between AFRL's Space Vehicles Directorate (AFRL/RV), AFRL's Office of Scientific Research (AFOSR), and the American Institute of Aeronautics and Astronautics (AIAA). AFRL/RV manages the competition, post-competition delivery and environmental testing, and launch vehicle coordination. AFOSR provides funding to the schools during the competition and continues funding the winners. AIAA sponsors the Flight Competition Review. There have been significant changes at the AFRL/RV Program Office over the past year and a half.

Current Structure

Previously the AFRL/RV Program Office was part of the AFRL/RVS division, but in the summer of 2010 it moved to the Integrated Experiments & Evaluation (RVE) division's Space Experiments and Programs

Branch (RVEP). This move has facilitated a variety of changes and helped to align the UNP programmatic requirements and deliverables with many common aerospace practices. It also allowed for lessons learned and technology development in UNP to be leveraged for other AFRL satellite efforts. The program was also placed in the Crux portfolio, a newly formed group in the branch focused on 50kg and smaller satellites. The intent is for lessons learned to be shared across the portfolio, which contains both the UNP Program Office and the Innovative Nanosatellite Experiments Program (INXS). The INXS Program is a series of CubeSats focused on developing AFRL capabilities in the CubeSat class spacecraft.

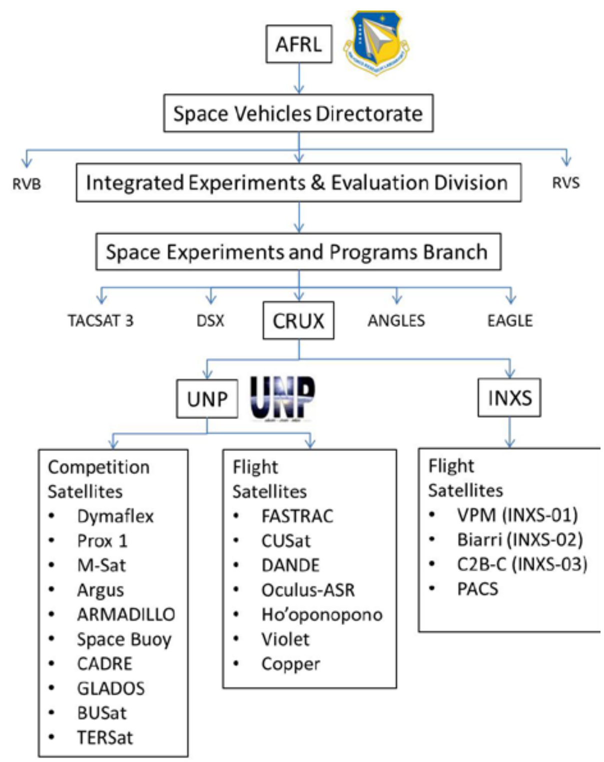

Figure 7: UNP within the AFRL organizational structure.

In-Reach Efforts

One of the largest impacts to the AFRL Program Office has been the implementation of an AFRL exposure program referred to as "in-reach." The intent of the in-reach effort is to provide exposure to all phases of the satellite design cycle to junior workforce members. As UNP typically has satellites in many phases of the design cycle this provides a unique opportunity to younger satellite engineers to see what requirements and gates must be met for satellite design, fabrication, testing, launch, and operations. The Program Office has benefited greatly from the partnership and from the additional personnel providing much needed assistance with managing and executing all aspects of the program. Currently the in-reach program exists only in the RVEP branch. However, it is currently being evaluated as a more formal program for the junior workforce across the Space Vehicle Directorate. Each junior workforce member has been given the responsibility of tracking two satellites in the competition phase, which involves going to their reviews and reading all of their documentation, organizing and leading one of the competition design reviews, and being the lead systems engineer for one of the post-FCR delivery satellites.

LEVERAGING UNP

The UNP community is comprised of leading academic institutions, world acclaimed professors, and highly motivated students. The Program Office has been attempting to leverage this highly capable group over the past year in ways that benefit the academic programs and the small satellite community as a whole. Since education is the number one priority of UNP, the key evaluator of whether any effort should be pursued is how it will affect the level of education in the program. All efforts are intended to be tools to assist the student teams.

Cooperative Ground Stations

With the growing number of small satellites, the need and opportunity for shared ground stations has increased. Over the past competition we have been suggesting that schools are GENSO compatible. GENSO, or the Global Educational Network for Satellite Operations, is a cooperative ground station effort that allows schools to leverage other amateur ground stations allowing for an increase in the amount of data they can get to the ground[7]. Although far from perfect, GENSO is one of the more mature cooperative ground station efforts and provides an immediate solution for the program. Currently the FASTRAC satellite has utilized the GENSO network for data packets and four current NS-7 schools are designing systems to be GENSO compatible.

In addition to the GENSO effort, the Program Office is still looking for other ground station solutions to help address the significant challenge of getting data to the ground.

AD&C Simulink Model

Developing a full six degree of field (6-DOF) attitude simulation model is both time consuming and challenging for schools to implement. Schools have designed and built their own with mixed results. However, there is strong crossover in the needs of many of the UNP schools in terms of a good 6-DOF simulation. The GNC group in the RVES branch has developed a 6-DOF model for their own utilization and model development. The Program Office released the model to the NS-7 schools as an optional tool for their GNC teams. Some schools have used the tool and have found mistakes. They have begun to develop their own modules to share with the Program Office. The GNC group benefits by user feedback that helps find errors in the model. Users may also provide their own developed modules to the community to use.

QuickSat

The Space Vehicles Spacecraft Technology Division has funded the development of a satellite design software tool called QuickSat as part of the Plug-n-Play effort. The tool allows for systems engineering trades to be made by defining the spacecraft payloads and subsystems and then defining each state, mission mode, and flight leg. Primarily useful for the initial mission design, QuickSat could potentially provide a standardized way to evaluate and provide feedback to each of the competition schools. The software also provides the ability for schools to capture documentation in a single location as well as some much needed consistency across the 10 student programs. Prior to UNP involvement, the software had not been used by a large user group. This was somewhat evident by the number of errors and requested features the students provided to the software developer. Although the potential for QuickSat is good, it is currently being evaluated to determine if it will be included in future UNP competition cycles, largely based off of the feedback from the student user base.

LESSONS LEARNED

Over the past 12 years of UNP's execution, there have been a number of lessons learned. Some of the lessons learned have been captured below.

The Need to Adapt

At the start of UNP, small satellites were just emerging in the space arena. CubeSats were barely spoken of and were somewhat a novelty. Until recently, UNP consisted of only 50kg satellites, primarily due to the state of the technology available. With the advent of the CubeSat growth, the National Science Foundation supporting CubeSat development, and the creation of the ELaNa program, the Program Office has been forced to change its perspective. With the focus of the program being a high quality educational experience, partnering with and encouraging schools to take advantage of these other programs is beneficial for all involved. This is key for UNP to stay relevant in a transient yet exciting time.

As a Program Office, demonstrating the ability to adapt is an important example for the student teams, who often times need to adapt to changing requirements or test results in their student programs and will need to apply the lesson in the highly volatile space industry after graduation.

Requirements Design

One of the biggest lessons learned in working with over two dozen spacecraft is the need for requirements-based design. Sorely missing from the academic curriculum in most engineering schools, requirements and constraints are the fundamental concepts that underpin a program. UNP has always focused heavily on this during the competition. However, a renewed effort to judge the readiness of the satellite based off of the requirements has been integrated into the post-FCR review process.

In a classic approach to systems engineering, requirements are captured in a Requirements Verification Matrix, which focuses on the flow down of requirements from the mission statement to the high-level systems requirements down to the payload/subsystem requirements. Lately, the Program Office has put a greater emphasis on capturing constraints and specifications and placing them on the same level as mission requirements. This is illustrated in Figure 8 where many areas are equally influencing the spacecraft design.

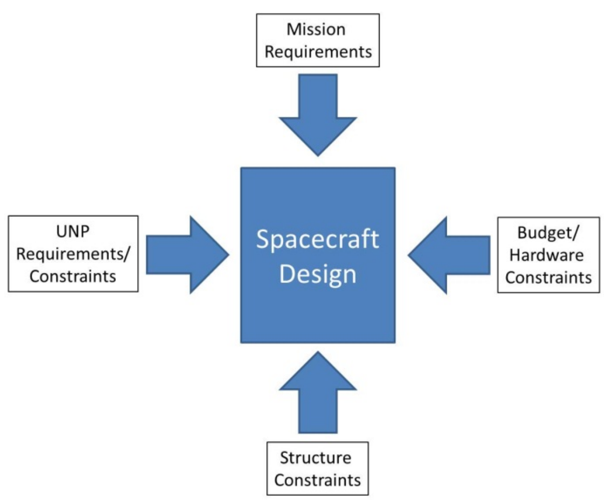

Figure 8: Requirements and constraints

Often schools will pick a form factor such as a CubeSat, which immediately limits the science or technology mission. Pretending to have a nice flow down, while side-loading the spacecraft design trade space often confuses students and poorly prepares them to deliver a working satellite on schedule.

Understanding how the mission requirements are traded at the system level with programmatic requirements, budget, off-the-shelf hardware, and predefined structural requirements allows students to have the true freedom of systems engineering design. Although this is especially true for the student satellite effort many of these lessons are applicable to large programs with significantly larger budgets. These programs must learn to stay on budget and on schedule, which often involves making concessions at the mission level (or understanding the system well enough to make high level trades, such as at the Concept of Operations (CONOPS) level).

Descope

A second lesson learned is the importance of descoping both at the individual school level as well as at the programmatic level. It is very tempting to incorporate a significant number of scientific instruments and technology demonstrations into a satellite to take advantage of a launch opportunity. However, the price seen at the Program Office is that schools are often unable to converge to a point where they are competitive at FCR in the required two years of the competition. Unlike many satellite programs, the competition phase is a scheduled review where each review is held according to a predefined length of time, regardless of the progress of the individual school. Although not as realistic as most satellite review processes, a valuable lesson is being taught to students: scheduling constraints can be as much of a driver as mission requirements, and in order to be competitive at FCR difficult descope choices oftentimes need to be made. During the NS-7 competition this was frequently brought up with schools.

The second level of descope in terms of lessons learned is at the UNP Program Office level. With the launching of a greater number of UNP satellites, the resources of the program are being stretched thin. In order to manage this, the Program Office has decided to stop support of a winner if they have not demonstrated development of the satellite by a certain point in the delivery phase (discussed more in the next section). Although this is a very difficult decision to make, it provides clear objectives, needed in any program, for both the Program Office and the school.

Post-FCR Review Process

A third lesson learned is the need for milestone-based reviews during the post-FCR process. A list of the programmatic reviews added can be seen in Table 1. Academic programs are challenged by the significant number of directions both the professors and students are pulled. Classes (both being taught and taken), internships, proposals, paper writing, and many other issues vie for the professor and students' time, and oftentimes it is the deadline of a review that helps propel a team towards reaching a goal. The UNP Program Office has learned that a well-defined post-FCR review process with clear deliverable requirements for each review is essential to reducing the time between FCR to delivery of the spacecraft to AFRL.

Table 1: Post-FCR review process and required deliverables

Review	Date	Deliverables
Deep Dive	FCR+1 month	-Prototype Engineering Unit -Flight CAD -Third Revision of Software
Interim Review	FCR+8 months	-Hammer test -Thermal Cycle Silver Boards -Vibe Test High Risk Boards
Interim Review	FCR+12 months	-as needed
Integration Readiness Review	FCR+16 months	-Simulated Comm Test -Silver Flatsat Charge Cycle -Silver Flatsat Day-in-the-life -Silver Flatsat Full Command Execution -Flight layouts completed
Pre-Ship review	FCR+24 months	-Flight Day-In-The-Life -Flight Complete Charge Cycle -Flight Command Execution

Launch Rush

The final lesson learned is the challenge the launch places on the design cycle. UNP satellites are secondary spacecraft and thus will always be driven by the launch schedule of the primary spacecraft. Also, because launch manifests are so rare, it is very difficult to turn down a launch option based on delays in the development of the satellite. However, it is critical for the Program Office, the PI, and the student team to accurately assess the true state of the hardware and to commit to launches in which the school is able to meet the hardware development timeline. If a program commits to a launch effort that is too early, it is very tempting for a program to cut corners to complete the hardware. Testing and documentation is not completed, resulting in an even longer development cycle and environmental testing phase. Having a well-defined post-FCR process with mandatory tests has helped in determining the true state of hardware and providing a better indication of the readiness to launch.

CONCLUSION

The University Nanosat Program has provided a unique educational experience to thousands of students and hopes to inspire the next generation of space engineers and scientists. The recent changes in the small satellite community have provided exciting opportunities for the program as it attempts to adapt and stay true to the core objective of student education while leveraging the many opportunities.

ACKNOWLEDGEMENTS

The authors of this paper would like to acknowledge the many professors and students whose vision, determination, and enthusiasm help the program succeed. We would also like to acknowledge the university PIs whose commitment to educate the next generation of space engineers at personal sacrifice is inspiring and much appreciated.

The authors would like to thank AIAA for their support of the Flight Competition Review. We would like to thank AFOSR, in particular Dr. Kent Miller and Dr. Julie Moses, who have funded the schools. Finally, we would like to thank AFRL's educational outreach branch (RVOT) for funding the AFRL Program Office and the RVEP branch enabling this program to exist.

REFERENCE

1. Obama, Barack, "State of the Union" Washington DC, 2009
2. Matthews, Christine, "CRS Report to Congress Science, Engineering, and Mathematics Education: Status and Issues," April, 2007
3. "National Space Policy," June, 2010
4. Walker, R. S.; Peters, F. W.; Aldrin, B.; Bolen, E. M.; Buffenbarger, R. T.; Douglass, J. W.; Fowler, T. K.; Hamre, J. J.; Schneider, W.; Stevens, R. J.; Tyson, N. D.; Wood, H. R. "Commission on the future of the United States Aerospace Industry: Final Report" Arlington, Virginia November 2002
5. GAO, "Environmental Satellite Acquisitions: Progress and Challenges," July, 2007
6. Munoz, S.; Greenbaum, J., Lightsey, E. G; Campbell, T.; Stewart, S.; Holt, G. "The FASTRAC Mission: Operations Summary and Preliminary Experiment Results," USU SmallSatellite Conference, Logan, UT 2011
7. Kief, C. "GENSO – A ground station is a terrible thing to waste," The AMSAT Journal, May/June, 2011

DISTRIBUTION LIST

DTIC/OCP 8725 John J. Kingman Rd, Suite 0944 Ft Belvoir, VA 22060-6218	1 cy
AFRL/RVIL Kirtland AFB, NM 87117-5776	2 cys
Official Record Copy AFRL/RVEP/David Voss	1 cy

This page is intentionally left blank.